IX Brazilian Symposium on GeoInformatics, Campos do Jordão, Brazil, November 25-28, 2007, INPE, p. 23-34.

The Development of a Large Scale Geospatial Telecommunications Application Independent from GIS Proprietary Mechanisms

Eliane Z. Victorelli Dias, Geovane Cayres Magalhães, Grace Kelly de C. Silva

Fundação CPqD
Rodovia Campinas/Mogi-Mirim, Km118,5 – CEP 13086-902 – Campinas – SP – Brazil

{eliane,geovane,grace}@cpqd.com.br

Abstract *This article presents the evolution of a very large geospatial database and application developed for telecommunications outside plant management. The needs for the construction of this system and the decisions taken during its development and consolidation phases are described. New challenges found in securing and expanding this type of system in today's market will be listed, as will be the need for a solution independent from the geographical information system (GIS) proprietary mechanisms. The alternatives examined and the approaches chosen to address the main points regarding the system evolution have resulted in a guide to similar initiatives in the area.*

1 Introduction

GIS or geographical information systems were developed using proprietary technology until the mid 90's. The business secret was exactly in how spatial data was stored, recovered and processed [MELO JUNIOR; CANDEIAS, 2005].

Currently, an important strategy in the information technology industry is to become independent from proprietary technology. GIS technology's role has become more important to organizations, and in order to take full advantage of its capabilities, spatial data must be shared and systems must be interoperable. However, this is not an easy goal to achieve, and the concepts, standards and technologies used to implement GIS interoperability have continuously evolved.

At first, data sharing between organizations that had different GIS providers was limited to data conversion. It later evolved to using transfer standards and the utilization of files with open formats. Soon after, some GIS began offering API for direct reading. Finally, backed by several organizations, efforts were made to define standards for geographical information exchange on different levels. These standards apply to issues that go from data format to service integration over the Web.

The GIS products, as well as the applications that make use of them, have been developed on open standards in order to guarantee a high level of interoperability between platforms, databases, and programming languages [ESSID, 2004].

The aim of this article is to demonstrate the impact that the need for interoperability has on a high-end, GIS-based solution that is a standard in its market. It offers a general view of where efforts were concentrated to ensure interoperability in a process of improving a solution for managing telecommunications outside plant.

This article lays out the historical facts on the development of a telecommunications outside plant management system and how it was conceived in alignment with the trends seen in the geospatial research domain. It then goes on to describe the market demands that motivated stepping up to GIS independence and lists the main characteristics of the new solution. Finally, the main issues involved in the process of making the system GIS-independent are set forth, as well as the alternatives that were evaluated and the solutions that were adopted.

2 History

CPqD OSP is a step up from SAGRE, one of the most complete telecommunications outside plant management systems ever developed. The SAGRE system was created to assist the companies that made up the Telebras System in offering better quality services. The goal was to manage the Brazil's entire telecommunications outside network, offering support to planning, design and operation in a more efficient manner.

The regional operators had different cultures, which led to them using outside plants with different technologies, topologies and representations of their facilities on maps. The initial demand for offering support to functions such as design and records on a more consistent basis led to the system's concept of flexibility and reconfigurability.

Throughout its history, the development of SAGRE was pioneering in several ways. Magalhães (1996) described the technological innovations introduced at the system's concept phase. Since then, every large step ahead taken towards making improvements to the system were oriented by trend analysis and up-to-date surveys.

Given the context, the choice for the GIS platform to offer support to the solution was made based on an international bidding process with a strict benchmark for evaluation.

The first versions of the system indicated that the records and design functions required the development of several user interfaces. To increase productivity and make maintenance easier, metadata was used to automatically generate the interfaces [MAGALHÃES; OLIVEIRA; CUNHA, 1995].

Another requirement that set the system apart from others of its kind was the need for offering support to long term project activity transactions and short term operations transactions simultaneously, allowing users to access multiple views of the network. In order to offer support in such scenario, a complex mechanism for long transactions using versions had to be created [DIAS; GRANADO; MAGALHÃES, 1995].

Making it possible to transfer data from a large number of paper or raster maps onto computer storage was, at that time, and continues to be, a huge challenge [MAGALHÃES, 2007]. This process was traditionally based on the proprietary formats of the GIS used, which made its acceptance burdensome and complex. In order to shorten deadlines and reduce costs, a conversion model built on a high-level, business object oriented language was specified. The development of a method for bulk conversion founded on this format gave way to the participation of domestic companies in the process. The initiative also ensured that an excellent-quality database would be put together, as the same integrity rules supported by the application were secured in the bulk conversion.

At the start of the data conversion process, one of the companies showed interest in controlling all the service provision data such that it were integrated to their outside plant records. To each new telephone installation was designated an ideal copper network using geographical criteria.

SAGRE then went on to become a critical mission system for Telesp, which was later acquired by Telefonica. Other operators, such as Sercomtel and GVT began similar procedures. Simultaneously, the design and inventory functions were upgraded to support Embratel's optical network architecture and to ensure that the Brasil Telecom and the others public phone regulation standards were met.

Integration of records data and that of service provision or other operational information is an excellent strategy, since it not only reduces operational process costs, but also allows the records database to be kept up-to-date on a constant basis.

The system is currently integrated to service order management, customer support and other systems, under environments with very different architectures. Previdelli e Magalhães [2002] describe some of the integration solutions taken, which go from file exchange queues to the use of message-oriented middleware or the provision of services in application server architecture.

Telefonica's outside plant is one of the largest existing spatial databases and includes the entire telephone network in the State of Sao Paulo. There are over 12,000,000 customers and 16,000,000 access lines in its records database. The provision of outside plant facilities is completely supported by the SAGRE system such that it is also integrated to several other operations support systems (OSS). This integration has lowered provision process costs by 40%. Over 200,000 service orders are processed monthly, and over 1,000,000 geographical inquiries are made [FARIAS; MAGALHÃES; PREVIDELLI, 2005].

Recently, management of project activities and the building of networks controlled by SAGRE were integrated into the company ERP. The integration has allowed for the costs of material and labor calculated automatically on project design to be used for the subcontractors payments. The phases involved in each endeavor are controlled in conjunction by the two systems. This way, the life span of projects has been reduced from weeks to days, and records updates have been ensured by eliminating backlog and as-built plants.

In early 2007, Telefonica received the Excellence Award for the Telecommunications Sector from GITA – Geospatial Information & Technology Association [GITA, 2007]. The award was granted in recognition to the quality and efficiency of integration and standardization of different operational procedures, which significantly brought down costs associated with these activities.

3 New Challenges

The new business opportunities for outside plant management products indicate that the market is more competitive than ever. Usually, the telecom companies have highly diversified requirements due to the wide variety of network technologies, services offered and business models found in telecommunications operators. Generally, in order for the system to meet the needs of a new customer, major changes have to be made to its features.

Another important factor in the sale of a product of this sort is the diversity in the magnitude of customers. There is a demand for both operators with millions of terminals and those with a few thousand. In light of this, the platforms used for small operators cannot be as costly as those that offer the power and performance necessary for a bigger customer.

On the other hand, current customers also upgrade their networks and expand their catalog of products and services, requiring major maintenance to all of their operating systems in order to evolve. Converged networks are becoming a reality and need to be managed by systems that allow operational procedures to become more agile and more efficiently utilize the facilities available at the service provider's plant. Networks are heading towards a new architecture with the goal of providing integrated services, something that is currently being called Quad Play, which are based on IP technologies to provide Internet, TV, voice, data and video transmission.

CPqD has oriented one of its lines of research, and consequently, the solutions obtained in its products, to fulfil the needs created by this scenario. The strategy established to keep the SAGRE system competitive and able to cater to the wide array of functional and non-functional demands was the development of a new version with a new architecture. The requirements that guided the definition of the new solution, the CPqD OSP were:

- Allowing for process distribution;
- Performing in accordance with different volumes of data;
- Supporting large variations in the number of users;
- Making integration with external systems easier;
- Yielding low costs for development and maintenance;
- Allowing for new features to be added quickly and;
- Being independent of the GIS platform, SGBD and application server.

4 CPqD OSP – The New Solution

4.1 Architecture

From the technological perspective, the CPqD OSP features the characteristics responsible for the success of the previous product but with new added concepts. As illustrated in Figure 1, CPqD OSP has an n-layer architecture which is based on JavaEE [JAVA, 2007], Open Geospatial Consortium, Inc ® standards [OGC, 2007], RBAC [SANDHU et al., 1996] and LDAP [WAHL et al., 1997], allowing for more flexibility and scalability.

Each layer plays well defined roles and communicates with each other using XML [XML, 2006]. This independence allows the replacement of one layer without affecting the entire architecture.

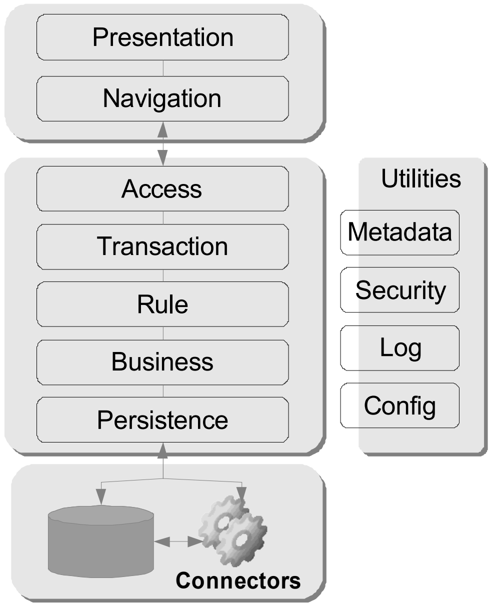

Figure 1: CPqD OSP Architecture

The Presentation and Navigation layers reside on the client side; they can be either a desktop client, web or mobile device. The other layers are on the server side. Access layer is responsible for user access control. Users with different profiles can access specific services and geographic areas. The Transaction layer controls the transaction that takes place when a service is requested, until it is committed or rolled back. Development is concentrated mainly on the Rule and Business layers - the Application Layer - where the business rules are implemented. The Persistence layer uses an enterprise data source concept for technology independent data access.

On top of this architecture was developed a metadata based framework that makes it possible to create solutions in a quicker and more standardized fashion. The goal of using this framework is bringing the focus of the efforts involved in the development to where they truly belong in the creation of a product: describing the domain objects and the rules that control this universe.

SAGRE already made use of metadata to generate its user interfaces, but the OSP solution intensified its use by applying it to data conversion, interface formats and business rules.

Regarding data conversion, Weiss and Dias (2004) defined the TOPML, which is a Geography Markup Language [OGC GML, 2004] application plan, designed to describe data pertaining to a telecommunications outside plant in which geographical information plays an important role.

4.2 Modules

The packaging of CPqD OSP is made up of several different modules (Figure 2) that can be used separately or put together into different combinations, which allow for better suiting each customer’s needs.

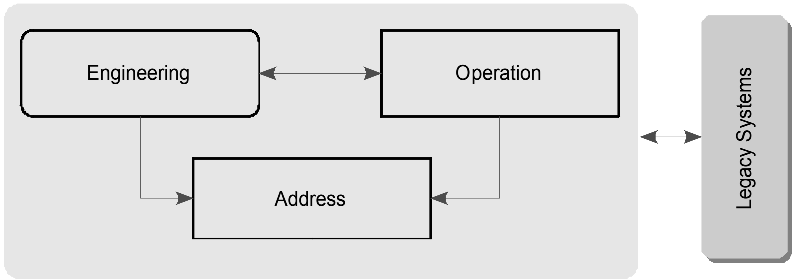

Figure 2: CPqD OSP Modules

The Address component is responsible for the business rules and the persistence of address objects. It offers a very important service of geocoding, which consists in determining a geographical coordinate of an address from a text description.

Also offered are interfaces that represent addressing objects to the outside world and that are utilized in different contexts that demand a wide variety of data recovery services from the component. These interfaces are based on OGC specifications.

In this case, special attention should be drawn to the use of the Filter Encoding Implementation Specification standard [OGC FE, 2005], which defines a format for XML-based filter expressions. These filter expressions restrict property values in order to create a subassembly of a group of objects.

The Engineering operates on top of the very popular Autocad Map CAD/GIS tool [AUTODESK, 2007]. This module covers the main use cases of inventory data maintenance for the outside plant. The inventory includes the elements of the copper, coaxial and optical networks, as well as the elements used in the basic infrastructure for building networks.

This module also offers support to the project activities for network maintenance and expansion. The functionalities provide support to the transitions between the stages in the life cycle of the project and different business and persistence rules are ensured for objects that are part of a project. The address component is used by the engineering module to add locations to network equipment.

The third module, Operation, covers the main use cases of network resource provisioning and trouble management. The business rules involved in registration and maintenance of the products and services are also supported by it. Reference to network information from the provisioning point of view is also offered, as is support to algorithms that determine the feasibility of providing a service to a specific address. Address components are used to associate a network facility to the customer's parcel.

The New Generation Operations Systems and Software (NGOSS) [NGOSS, 2007] specifications, which offers means to assist communications service providers in managing their businesses, including the SID model [SID, 2007] for shared information and the eTom map of telecommunications processes [eTOM, 2005] were widely studied and used as guidelines for the development of these services [SCHMIDT et al., 2007].

As is true for the SAGRE, integration between the Engineering and Operation modules is a factor that sets the CPqD OSP solution apart from others. It allows for provisioning operations to act on current information while viewing the proposed modifications. Aside from this, network modification operations preserve the integrity of the provisioning data and can provide the information used for planning network cuts. Even though the modules are a part of the same solution, one of the new business requirements was that they offer the capability of being implemented independently.

The guidelines that oriented the development of CPqD OSP were independence from GIS and the use of open standards for interoperability. These requirements affect mainly the presentation and persistence layers. All of these features were highly challenging and will be discussed in detail in the next sections.

5 GIS Independence from Proprietary Mechanisms

On the path to a solution for outside plant management independent of vendors proprietary solutions, the biggest challenge faced was, without a doubt, GIS independence. This did not come as a surprise, as this solution is strongly founded upon spatial information. The impact of this requirement fell upon several important components of the solution, such as the geographical data model, long transaction control, the client application and the rendering mechanism. For every component, several alternatives were analyzed using cost, deadline and architectural criteria. A presentation of the main characteristics of this study follows.

5.1 Persistence Model

An important step for GIS independence consisted in adopting a persistence layer that made the application flexible so that it would support different geographical data models.

The use of a well-defined interface for manipulating geographical data makes the application independent of the means of persistence and changes made to the structure of the geographical data will not affect the application layer.

The spatial data interface defines a structure that describes a spatial object and standardizes access to this data type by the application.

Insertion, removal, modification and reference operations for any spatial object must be carried out in the persistence layer. These operations must read from the persistent means and generate an object that implements the spatial object interface and write onto the persistent means from a spatial object.

Independent alternatives were sought out for the spatial data interface and for the spatial data storage models.

5.1.1 Storage models for spatial data

The data model adopted presumes a geographical object’s data being isolated according to its type. The alphanumerical information and spatial information are stored each in different entities. This allows for several graphical replicas to be represented without creating redundancy of alphanumerical information in the database.

The application of outside plant management commonly resorts to several layouts. Usually, these layouts are in planar coordinate system and the land base data is stored in other spatial coordinate system due to large areas being covered.

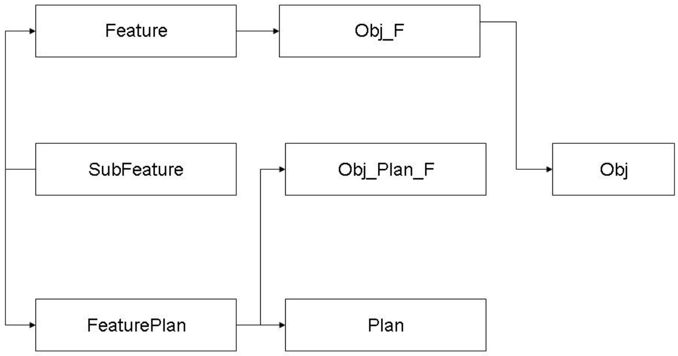

Figure 3: Data Model

5.1.2 Geographical data manipulation interface

For the representation of geographical data, the OGC specifications were quite natural and were followed in defining this interface. Some open source components offered OGC specifications, such as the GeoTools.

However, CPqD already had an interface implementation for the spatial data called SpatialObject, and some applications already made use of this interface. Implementation of SpatialObject made use of concepts very similar to those required for the generic interface. However, it would also be of interest to use the GeoTools library to read the data from the persistent means. A drawback is that the data read by GeoTools is stored in JTS component objects. The first alternative would be to create routines to convert a SpatialObject into a JTS component object and vice-versa. In this case, it would not be possible to develop objects with sub-features containing very complex geometries.

Re-using SpatialObject and making a few changes to its structure was also an option considered. The objects would store coordinates using JTS. It would then be possible to have sub-features with more complex geometries.

The second alternative allowed for more functionality. However, the first alternative was chosen, as it supported the use of sub-features, which was an important requisite, and lowered development costs. This decision was based on factors which indicated that future versions of GeoTools would no longer use JTS.

5.2 Controlling long transactions

The SAGRE solution supports a powerful long transaction mechanism based on version control. However, it is native of the GIS used. Since the goal of the CPqD OSP solution was to be independent from GIS, a new mechanism had to be implemented. The challenge was big, seen as the users would not like to be delivered a product with functionalities that were inferior to those offered by the previous version of the product.

The first alternative examined consisted in implementing all of the project control functionalities as well as version support, similarly to SAGRE. This would, however, be very expensive. In this context, the use of a few available version control components was examined. However, a mandatory requisite was that the project views could be made available in the main base during the engineering phase, before the project was constructed. The components studied do not offer this facility and developing it based on version mechanisms supported elsewhere would be a risk.

An approach combining cost and offered functionalities was taken for the version mechanisms development. The choice made was to develop a simplified model of project modification control, with which every operation carried out on an object is stored in the same version. Dependencies between objects is less sophisticated than that developed for SAGRE; for example, when an object depends on another it is not possible to determine what change motivated the dependency.

However, the simplified mechanism meets the current needs; its development and maintenance were less complex and it can be easily upgraded in case functionalities offered by a control based on a transaction version becomes necessary.

5.3 Flexibilization of the Engineering Module Client Application

To put it in general terms, the client application carries out the mediation and control of the flow of information between the attribute manager, the map and the application server.

It features functionalities that retrieve geographical data from the map and sends it to the application server and vice-versa. In order to achieve this, a specific client application must be developed depending on the front-end used to represent the geographical data. This is therefore one of the solution's section that is affected most by the requisite of being independent from GIS.

The OGC defines the Web Map Service [OGC WMS, 2004] and Web Feature Service [OGC WFS, 2005] for geographical data exchange between a server and a client application.

The WMS service is a way to produce maps from geo-referenced data and carry out queries on its attributes from information coming in simultaneously from multiple heterogeneous remote servers. The map is the visual representation of the geospatial information, and not the information itself.

The WFS allows a client to retrieve and update geospatial data encoded in Geography Markup Language (GML) from multiple Web Feature Services. The specification defines interfaces for data access and manipulation operations on geographic features, using HTTP as the distributed computing platform. Via these interfaces, a Web user or service can combine, use and manage geodata -- the feature information behind a map image -- from different sources.

A standardized interface had to be defined for the client application just as for the other features of the OSP solution. Both of the specifications mentioned were used in different contexts.

5.4 Rendering

The process of generating a graphical representation of an object is also called rendering. In order for the GIS independence to be fulfilled, it was also necessary to seek out alternatives to the development of a feature rendering module that could be used alongside several graphical devices.

Apart from that, it is quite common for users of a GIS based solution to want to adapt symbols to the visual standards used in their organization. Therefore, the rendering solution also had to be prone to this kind of customization being made by users in their own environments.

It was observed that the drawing process had to be divided into at least two stages to represent objects in different devices, ensuring that the code of rules for rendering could be re-utilized after devices were replaced. The first stage would contain all of the rules on how to draw an object, with no connection to the device on which the drawing would be presented. It was necessary to assume the existence of a group of devices on which previously defined shapes referenced by names could be represented, even if the method for obtaining the representation differed between devices in the group. Therefore, it was presumed that simple entities such as text, lines, polygons and symbols could be represented on any graphical device.

The output of the first stage is a set of entities or drawing primitives called design logical entities, and are not associated to any graphical device. These entities have to be submitted to a process of translation in order to be displayed on the device in question. The translation module, which is device dependant, is called a driver.

Part of the rendering process is run on the server-end, while the rest is run on the client-end. Server processing is responsible for generating the design logical entities, such as defining lines, points, colors and other elements that make up an object. The client is then responsible for transforming logical entities into design entities and has the code specific to the device on which the drawing will be generated. The figure below illustrates how the rendering module works.

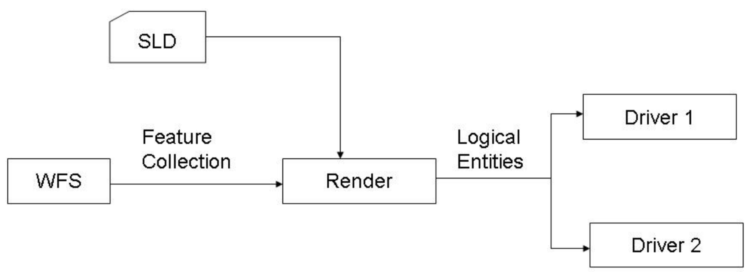

Figure 4: Rendering Module Components

The language adopted for the description of the logical entities was the Styled Layer Descriptor [OGC SLD, 2007], which is an OGC specification for the rendering of features. This standard can be used in any context where there is a need for flexibility on the way objects are displayed and allows for declarative customization.

This standard was chosen for having consolidated characteristics and for representing the results of the experiences of several georeferencing specialists. Besides this, there are open source implementations for its reading and rendering capabilities. However, SLD does not completely suit the needs of the project and an extension of the standard was developed.

Breaking away from the standard makes it difficult to use the tools available on the market that rely on SLD. However, the greatest advantage to this approach is the flexibility for altering post-implementation rendering aspects, enabling users to better customize their own symbols.

6 Conclusion

The changes made to an outside plant management system in order to make it GIS independent have been presented. This is a costly and demanding effort, but this project has proven it feasible.

It was also made clear that the creation of well defined interfaces outlining the functionalities strongly linked to GIS alongside the adoption of interoperability standards are generally the least expensive and most efficient way to achieve this goal.

7 Acknowledgments

A major portion of this article was obtained from internal reports written by the staff at the CPqD's Outside Plant Systems Management, which is comprised of dedicated and highly competent professionals. The technological evolution of a system of such magnitude taking place alongside support and maintenance of critical mission environments is only made possible by the brilliance and team effort of this group.

The authors wish to thank FUNTTEL (Fundo para o Desenvolvimento Tecnológico das Telecomunicações) for their support to this work through Triple Play Project.

8 References

AUTODESK (2007) Autodesk, Inc., Autocad Map. http://www.autodesk.com/autocadmap.

DIAS, E.; GRANADO, S.; MAGALHÃES, G. (1995) "Uso de Versões na Garantia de Consistência em Ambientes Mistos de Projetos e Operação" Anais do X Simpósio Brasileiro de Banco de Dados. Recife, p. 321 - 334.

ESSID, M.; BOUCELMA, O. (2004) "Mediated Geographic Web Feature Service. Anais do Brazilian Symposium On Geoinformatics", Inpe, p. 331 - 342.

eTOM (2005) "Enhanced Telecom Operations Map (eTOM) The Business Process Framework" GB921 v.6.1 - Release 6.0 edition TM Forum.

FARIAS, M.; MAGALHÃES, G.; PREVIDELLI, C. (2005) "Geospatial Database for Operations and Engineering" Oracle Spatial User Conference. http://www.oracle.com/technology/products/spatial/htdocs/spatial_conf_0503_idx.

GITA (2007) "Telefonica S.A. Receives GITA's Excellence Award" http://gita.org/resources/news/press_releases/3_2007-excellence_tsa.asp.

JAVA (2007) Sun Microsystems, Inc. http://www.sun.com/java.

MAGALHÃES, G.; OLIVEIRA, J.; CUNHA, C. (1995) "Métodos de Objetos para Construção de Interfaces Visuais Dinâmicas" Anais do IX Simpósio Brasileiro de Engenharia de Software. Recife, p. 143 - 158.

MAGALHÃES, G. (1996) “O Projeto SAGRE” In: CÂMARA, G.; CASANOVA, M.; HEMERLY, A. Anatomia de Sistemas de Inf. Geográfica. Campinas, Cap. 12.

MAGALHÃES, G. (2007) “A Better Way to Conversion: The Open, Incremental, GIS Free Approach” In: GITA´S ANNUAL CONFERENCE, 30., 2007, San Antonio.

MELO JUNIOR, J.; CANDEIAS, A. (2005) “SIG e sua interoperabilidade utilizando servidores de WEB” Anais XII Simpósio Brasileiro de Sensoriamento Remoto. Goiânia: Inpe, p. 2273 - 2280.

WAHL, M.; HOWES, T.; KILLE, S. (1997) "Lightweight Directory Access Protocol (v3)," IETF RFC 2251; http://www.ietf.org/rfcrfc2251.

NGOSS (2007) “New Generation Operations Systems and Software 6.0 Solution Suite” TM Forum http://www.tmforum.org/tech/NGOSS/1911.

OGC (2007) Open Geospatial Consortium, Org., OpenGIS Specifications. http://www.opengeospatial.org/standards.

OGC FE (2005) “Filter Encoding” Version 1.1 MA: Open GIS Consortium, Inc. < http://www.opengeospatial.org/standards/filter.

OGC GML (2004) “Geography Markup Language Encoding Specification” Version 3.1.1 Open GIS Consortium, Inc. http://www.opengeospatial.org/standards/gml.

OGC LS (2004) “Location Services: Core Services [Parts 1-5]” Version 1.0. MA: Open GIS Consortium, Inc. http://www.opengeospatial.org/standards/olscore.

OGC SLD (2007) “Styled Layer Descriptor Profile of the Web Map Service” Version 1.1 MA: Open GIS Consortium, Inc. http://www.opengeospatial.org/standards/sld.

OGC WFS (2005) “Web Feature Service” Version 1.1 MA: Open GIS Consortium, Inc. http://www.opengeospatial.org/standards/wfs.

OGC WMS (2004) “Web Map Service” Version 1.3 MA: Open GIS Consortium, Inc. http://www.opengeospatial.org/standards/wms.

PREVIDELLI, C.; MAGALHÃES, G. (2002) “Moving Geospatial Applications Towards a Mission Critical Scenario” Procedings of GITA 2002 Tampa.

SANDHU, R.; COYNE, E.J.; FEINSTEIN, H.L.; YOUMAN, C.E. (1996). "Role-Based Access Control Models". IEEE Computer, P. 38-47. IEEE Press.

SCHMIDT Simone et al.(2007) “Mapping OSS Products Using the eTOM Business Processes Framework” Proceedings Of The International Workshop On Telecommunications, Santa Rita do Sapucaí, p.58-65.

SID (2007) “SID Solution Suite” GB922 & GB926 NGOSS Release 7.0 TM Forum http://www.tmforum.org/page32555.

WEISS, G.; DIAS, E. (2004) “Moving Telecom Outside Plant Systems Towards a Standard Interoperable Environment” Lecture Notes In Computer Science, Springer Berlin / Heidelberg, v. 2004, n. 3124, p.1246-1251, 28.

XML (2006) “Extensible Markup Language” Version 1.1 W3C. http://www.w3.org/TR/xml11/.